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Coastal Wetland Restoration Bibliography

by David J. Yozzo, John P. Titre

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	<u>Task</u>		<u>Task</u>
CP	Critical Processes	RE	Restoration & Establishment
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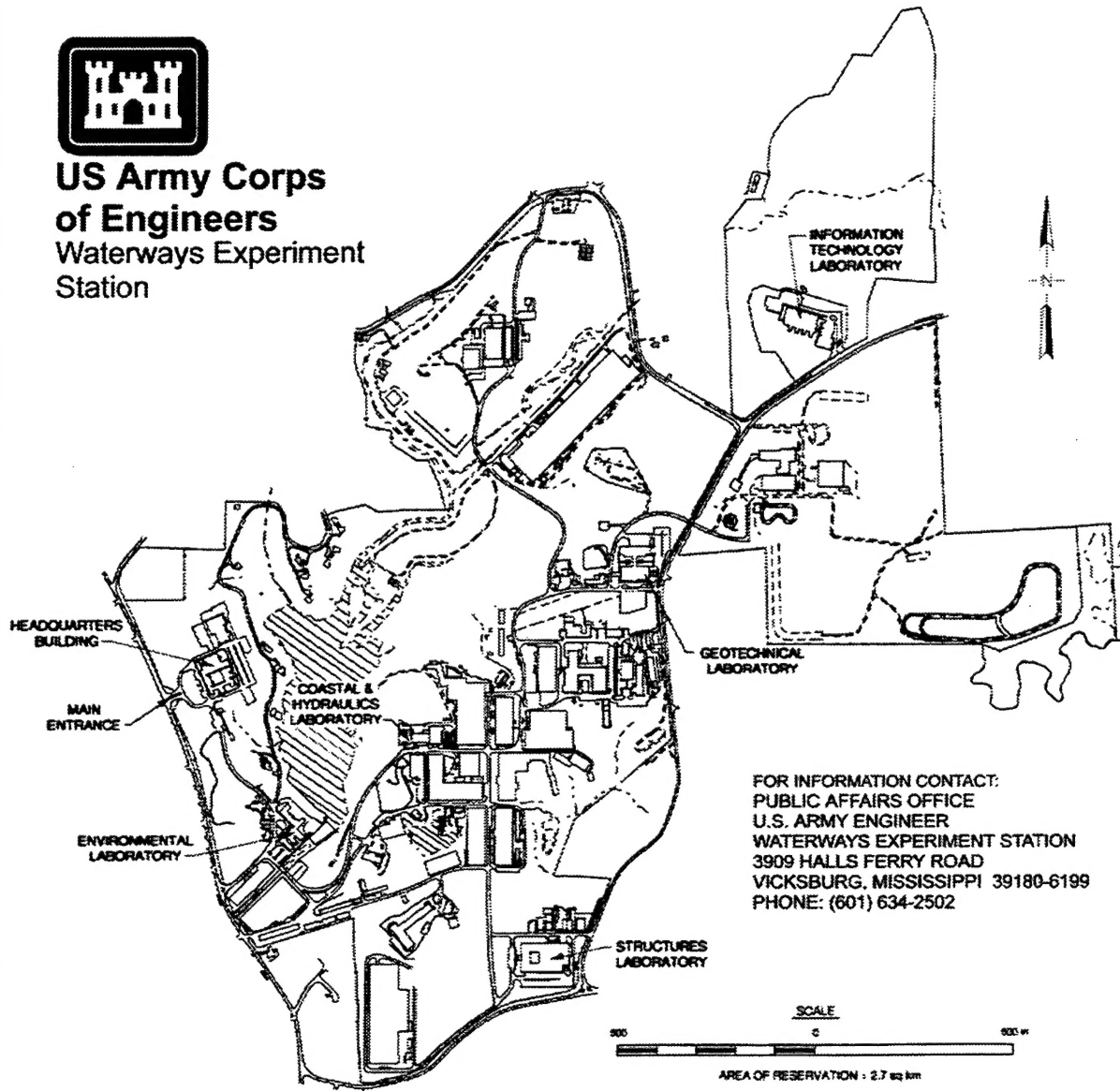
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Wetland Restoration

Coastal Wetland Restoration Bibliography (TR WRP-RE-20)

ISSUE:

The restoration of coastal wetlands is an area of increased emphasis within the civil works program of the U.S. Army Corps of Engineers. A comprehensive guide to the diverse literature on coastal wetland restoration is needed by District biologists, engineers, and planners.

OBJECTIVES:

This bibliography was compiled to provide biologists, engineers, and planners at Corps Districts and other agencies/institutions with a guide to the diverse body of literature on coastal wetland restoration. The availability of this information should aid in the development of technically sound restoration plans and guide efforts to evaluate wetland restoration projects in the coastal zone using the best information available.

SUMMARY:

This bibliography consists of 435 literature citations on coastal wetland restoration in the

United States. Sources include scientific journals, conference proceedings, and technical reports from various Federal and State agencies. The bibliography is organized by the following wetland habitat types: (a) tidal marshes, (b) mangroves, (c) seagrasses, and (d) miscellaneous. Selected key citations in each section are briefly annotated, and a subject index is provided.

AVAILABILITY OF REPORT:

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Preface

The work reported herein was authorized by Headquarters, U.S. Army Corps of Engineers (HQUSACE), as part of the Wetland Restoration and Establishment Task Area of the Wetlands Research Program (WRP). Dr. Russell F. Theriot, U.S. Army Engineer Waterways Experiment Station (WES), was the Wetlands Research Program Manager. Dr. Mary C. Landin, WES, was the Task Area Manager. The work was performed under the Technical Standards and Guidance for Wetlands Restoration and Creation Work Unit of the WRP for which Dr. Landin was the Principal Investigator.

The bibliography was compiled by Dr. David J. Yozzo and Mr. John P. Titre, Environmental Laboratory (EL), WES. Dr. Yozzo was supported by a National Research Council-WES Research Associateship.

The authors wish to thank the staff of the WES Library for their assistance in locating and obtaining bibliographic materials. Mr. William Hansen, Institute for Water Resources, provided comments on an earlier draft. Technical reviews were provided by Dr. Landin and Dr. Gary L. Ray, WES.

The report was prepared under the general supervision of Mr. H. Roger Hamilton, Chief, Resource Analysis Branch; Dr. Douglas Clarke, Acting Chief, Coastal Ecology Branch; Dr. Morris Mauney, Chief, Wetlands Branch; Dr. Robert M. Engler, Chief, Natural Resources Division; Dr. Conrad J. Kirby, Chief, Ecological Research Division, and Dr. John Harrison, Director, EL.

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Introduction

The restoration of coastal wetlands is an area of increased emphasis within the civil works program of the U.S. Army Corps of Engineers (USACE). Congressional authorities such as Section 404 of the Clean Water Act of 1972, Section 1135 of the Water Resources and Development Act of 1986, and Section 204 of the Water Resources and Development Act of 1992 are providing more opportunities to pursue restoration initiatives and to develop improved techniques for the evaluation of restoration projects and programs in coastal and inland waters. The Corps' Wetlands Research Program (WRP) was initiated in 1991 to address the needs expressed by the national Wetlands Policy Forum Report for protecting and managing wetlands. The purpose of the WRP is to provide environmentally sound, cost-effective techniques to examine and provide information on a variety of wetland research and development topics. This bibliography was compiled under the Technical Standards and Guidance for Wetlands Restoration and Creation Work unit of the WRP. The objective of this work unit was to provide improved technical guidance for new and ongoing wetland restoration and creation efforts, with an emphasis on coastal, herbaceous wetlands.

Coastal wetlands in the United States have historically experienced degradation and loss resulting from various activities, including draining and filling for conversion to uplands; industrial and agricultural pollution; navigation impacts, natural and man-induced erosion, and habitat modification. The recognition of the myriad of benefits of coastal wetlands, including erosion and flood control, maintenance of water quality, and provision of habitat for fish, shellfish, and wildlife prompted efforts to restore or create coastal wetlands. Some of the earliest attempts to create or restore coastal wetlands were initiated by the Corps in the early 1970s, as part of the Dredged Material Research Program. These efforts resulted in the development of new engineering technologies for sediment stabilization and vegetative plantings, and resulted in the identification of new areas for research, such as the comparison of functional equivalency between restored/created and natural wetlands. Additional USACE programs that have included opportunities for coastal wetland restoration include the Dredging Research Program, Dredging Operations and Technical Support Program, Dredging Operations and Environmental Research Program, Wetlands Research Assistance Program, and the Characterization and Restoration Wetlands Research Program. Other Federal and State agencies and institutions have developed restoration initiatives, and Federal legislation (The Coastal Wetlands Planning, Protection, and

Restoration Act of 1990) has been enacted in support of multiagency participation in restoration activities in the coastal zone.

A considerable amount of published material on restoration of coastal wetlands is available, in both the primary and gray literature. The majority of this literature is on the restoration of temperate coastal wetlands, primarily *Spartina alterniflora* marshes; previous investigators have summarized this literature and available resources on this subject (Matthews and Minello 1994a,b). Considerable literature documents the restoration of subtropical and temperate seagrasses. Subtidal seagrass beds are closely linked to emergent coastal wetland systems and are at least as vulnerable as tidal marshes to environmental impacts. Like tidal marshes, seagrass beds provide a high-quality "nursery habitat" in shallow coastal ecosystems and are critical to early life stages of many estuarine and coastal fishery species. Thus, seagrasses are often considered in the restoration and management of coastal wetlands (Fonseca 1990). Mangrove forests are also subject to habitat modification and degradation activities. Few publications document the restoration of mangroves relative to the aforementioned saltmarsh and seagrass ecosystems. Fewer publications document the restoration or creation of tidal freshwater marshes, despite the relative abundance and proximity of these unique and productive wetlands to population centers in the major tributaries along the Atlantic coast and elsewhere.

This bibliography consists of 435 literature citations on coastal wetland restoration in the United States. Sources include scientific journals, conference proceedings, and technical reports from various Federal and State agencies. The bibliography is organized by the following wetland habitat types: (a) tidal marshes, (b) mangroves, (c) seagrasses, and (d) miscellaneous. The last category includes citations that document restoration of multiple or adjacent habitats within a particular geographic region (i.e., restoration of seagrasses and mangroves in Tampa Bay, Florida) and compilations of conference/workshop proceedings on coastal habitat restoration. Selected key citations in each section are briefly annotated. The majority of the citations listed document specific restoration projects. Citations have also been included that describe restoration theory or resource management issues in coastal habitat restoration. Citations on habitat creation, including beneficial-use projects are included, although they may not necessarily document restoration of a particular site or habitat type to "predisturbance" or "historical" conditions. Also included are citations documenting ecosystem-level processes that relate specifically to restoration/creation efforts in coastal wetlands.

This bibliography is intended for a broad range of users. Resource managers, environmental planners, biologists, and engineers at Corps Districts and other Federal and State agencies/institutions who require a comprehensive guide to the complex and diverse body of literature on coastal wetland restoration should benefit from the resources compiled here. The anticipation is that the bibliography will aid in the development of technically sound restoration plans and guide efforts to evaluate wetland restoration projects in the coastal zone using the best information available.

Tidal Marshes

Annotated Entries

Allen, E.A., Fell, P.E., Peck, M.A., Gieg, J.A., Guthke, C.R., and Newkirk, M.D. (1994). "Gut contents of common mummichogs, *Fundulus heteroclitus* L., in a restored impounded marsh and in natural reference marshes," *Estuaries* 17, 462-71.

Gut contents of mummichogs (*Fundulus heteroclitus*) leaving and entering tidal ditches were compared at a restored impounded valley marsh and two nearby reference marshes in Connecticut. Major food items were detritus, algae, amphipods, tanaisids, copepods and insects. Fish from the restored marsh consumed less food per unit body weight than fish from the reference marshes.

Boesch, D.F., Josselyn, M.N., Mehta, A.J., Morris, J.T., Nuttle, W.K., Simenstad, C.A., and Swift, D.J.P. (1994). "Scientific assessment of coastal wetland loss, restoration and management in Louisiana," *Journal of Coastal Research*, Special Issue No. 20.

This report summarizes the findings of an expert panel commissioned to examine the problem of wetland loss in coastal Louisiana and recommend research and management needs. The report focuses on processes of wetland loss in coastal Louisiana, including human contributions. Management options are discussed and a comprehensive management approach, including provision for wetland restoration under the Coastal Wetlands Planning, Protection and Restoration Act (CWPPRA), is outlined.

Broome, S.W., Seneca, E.D., and Woodhouse, W.W., Jr. (1988). "Tidal salt marsh restoration," *Aquatic Botany* 32, 1-22.

An overview of the ecological functions of coastal salt marshes and techniques for their restoration, particularly following human perturbation such as dredge and fill activities and discharge of toxic materials such as petroleum products. Factors which determine success of vegetation establishment are discussed, including tidal regime, slope, wave exposure, soil physico-chemistry, nutrient supply and salinity. Examples of marsh restorations are provided and illustrate restoration/enhancement of dredged material disposal sites, shoreline stabilization, and

revegetation of a marsh destroyed by an oil spill. Further research is needed to confirm the success of marsh restoration based on ecological functions, including the faunal component.

Fell, P.E., Murphy, K.A., Peck, M.A., and Recchia, M.L. (1991).

"Re-establishment of *Melampus bidentatus* (Say) and other macroinvertebrates on a restored impounded tidal marsh: Comparison of populations above and below the impoundment dike," *Journal of Experimental Marine Biology and Ecology* 152, 33-48.

Macroinvertebrate communities were compared at an impounded marsh in Stonington, Connecticut, which had been restored from a *Typha*-dominated system to a typical salt marsh within 12 years after the introduction of tidal flooding. Comparison was made to marshes below the impoundment dike, which were dominated by *Spartina patens* and short *S. alterniflora*. *Melampus bidentatus* and other invertebrates have become reestablished on the impounded marsh. Mean density of *Melampus bidentatus* was greater on the marshes below the dike; however, mean snail biomass was greater on the restored impounded marsh.

Frenkel, R.E., and Morlan, J.C. (1991). "Can we restore our salt marshes? Lessons from the Salmon River, Oregon," *The Northwest Environmental Journal* 7, 119-35.

The progress of salt marsh development was monitored for 10 years following the removal of a dike and restoration of tidal flow to pastures along the Salmon River Estuary, Oregon. Environmental parameters evaluated included elevation, tidal creek morphology, soil characteristics, plant community structure, and above-ground primary production. Guidelines on project construction and monitoring are presented to aid in future marsh restorations in the Pacific Northwest.

Gilmore, R.G., Cooke, D.W., and Donohoe, C.J. (1983). "A comparison of the fish populations and habitat in open and closed salt marsh impoundments in east-central Florida," *Northeast Gulf Science* 5, 25-37.

Ichthyofauna of two marsh impoundments along the Indian River lagoon were compared: one closed to tidal influence and one opened to the tide via a single 80-cm diameter culvert. The closed impoundment contained a depauperate ichthyofauna consisting of 12 species and was characterized by stressed environmental conditions. The open impoundment contained 41 fish species and exhibited extensive regrowth of typical emergent marsh vegetation.

Josselyn, M., ed. (1982). "Wetland restoration and enhancement in California," *Proceedings of a Conference, February 1982, California State University, Hayward*. California Sea Grant Report T-CSGCP-007, Tiburon Center for Environmental Studies, Tiburon, CA.

A compilation of papers from a workshop on marsh restoration held at California State University, Hayward, in February 1982. Topics include a summary of restoration projects in California; restoration goal development; legal and institution constraints on wetland restoration; wetland engineering; restoration project

monitoring; vegetation, benthic invertebrate and fish communities of restored wetlands.

Josselyn, M.N., and Buchholz, J. (1984). "Marsh restoration in San Francisco Bay: A guide to design and planning," Technical Report 3, Tiburon Center for Environmental Studies, Tiburon, CA.

This report details the restoration of tidal wetlands in the San Francisco Bay area and provides guidelines to successful habitat design for future restoration projects. The primary emphasis of the report is on biological components of restored habitat; however, considerable information is provided on sedimentation and hydrology, as well. Restoration project objectives and monitoring programs for marsh restorations are discussed. Case studies of previous and ongoing restoration projects in Marin County are provided.

Landin, M.C., Webb, J.W., and Knutson, P.L. (1989). "Long-term monitoring of eleven Corps of Engineers habitat development field sites built of dredged material, 1974-1987," Technical Report D-89-1, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

This report documents the long-term study of 11 habitat development sites built on dredged materials by the U.S. Army Corps of Engineers Dredged Materials Research Program (DMRP). Summary chapters provide construction details and monitoring results for each site, with comparison to natural reference conditions. Objectives of the monitoring study were to (a) document long-term stability of dredged material disposal sites, (b) determine successional changes, (c) relate site functions and values to natural reference sites, and (d) demonstrate the feasibility of using dredged materials for habitat development projects. Recommendations concerning soils, plant propagation and planting methods, engineering design and construction, and estimating costs are provided for future habitat development and restoration using dredged materials in inland and coastal waters.

Peck, M.A., Fell, P.E., Allen, E.A., Gieg, J.A., Guthke, C.R., and Newkirk, M.D. (1994). "Evaluation of tidal marsh restoration: Comparison of selected macroinvertebrate populations on a restored impounded valley marsh and an unimpounded valley marsh within the same salt marsh system in Connecticut, USA," *Environmental Management* 18, 283-93.

Macroinvertebrate communities on a restored impounded valley marsh were compared with that of a nearby unimpounded valley marsh in Stonington, CT. The snail, *Melampus bidentatus*, and the ribbed mussel, *Guekensia demissa*, were sampled along transects from the marsh edge to the upland and along creek banks and mosquito ditches. Density of *Melampus* was highest on the unimpounded marsh; however, mean snail biomass was greater on the restored impounded marsh. *Guekensia* densities were comparable at creek-bank sites in both marshes; however, total biomass of *Guekensia* was significantly greater on the unimpounded marsh.

Rey, J.R., Shaffer, J., Tremain, D., Crossman, R.A., and Kain, T. (1990). "Effects of re-establishing tidal connections in two impounded subtropical marshes on fishes and physical conditions," *Wetlands* 10, 27-45.

An impounded subtropical salt marsh was reconnected to the Indian River Lagoon in east-central Florida via installation of culverts. Abundance of marsh resident fish species decreased significantly following installation of culverts; however, abundance of transient species increased by nearly two orders of magnitude. Alteration of marsh hydroperiod is the dominant factor influencing patterns of fish utilization, abundance, and species composition.

Roman, C.T., Garvine, R.W., and Portnoy, J.W. (1995). "Hydrologic modeling as a predictive basis for ecological restoration of salt marshes," *Environmental Management* 19, 559-66.

A numerical model was developed to predict tide height levels resulting from various alternatives for a proposed marsh restoration project on the Herring River, Massachusetts. Using the model output and elevation data for flood-prone adjacent areas, ecologically sound and responsible management plans can be formulated. The model was successfully applied to a marsh restoration project in Provincetown, MA, and enables scientists and managers to assign a degree of predictability in marsh restoration planning.

Roman, C.T., Niering, W.A., and Warren, R.S. (1984). "Salt marsh vegetation change in response to tidal restriction," *Environmental Management* 8, 141-50.

Changes in vegetation communities at six Connecticut salt marshes are documented in response to restriction of tidal exchange. Tide gates, causeways, and dikes have historically been employed in this region for purposes of flood control, mosquito management, and salt hay farming. Tidal restriction resulted in a substantial decrease in soil water salinity, lowering of the water table, and a drop in relative marsh surface elevation at each of the six study sites. These factors favor the establishment and spread of invasive species such as common reed (*Phragmites australis*), along with a loss of *Spartina* marsh. Restoration of *Phragmites*-dominated areas is possible following reestablishment of the normal tidal prism. Large-scale regional restoration efforts are recommended.

Shreffler, D.K., Simenstad, C.A., and Thom, R.M. (1990). "Temporary residence by juvenile salmon in a restored estuarine wetland," *Canadian Journal of Fisheries and Aquatic Science* 47, 2079-84.

Movements and marsh residence times were determined for juvenile Pacific salmon utilizing the Lincoln Avenue wetland system in the Puyallup River estuary, Tacoma, WA. Residence times for various species ranged from 1 to 43 days; however, evaluation of the benefit of marsh residency is constrained by lack of data from suitable reference wetlands.

Shreffler, D.K., Simenstad, C.A., and Thom, R.M. (1992). "Foraging by juvenile salmon in a restored estuarine wetland," *Estuaries* 15, 204-13.

Foraging by juvenile chum salmon (*Oncorhynchus keta*) and fall chinook salmon (*O. tshawytscha*) was studied in a restored estuarine wetland in the Puyallup River, Washington. Juvenile salmon fed primarily on chironomid insects (midges, larvae, pupae, and adult life stages). Although the restored wetland provided abundant forage for juvenile salmonids during estuarine residency, the functional equivalency of restored estuarine habitats relative to natural habitats remains untested.

Simenstad, C.A., and Thom, R.M. (1996). "Functional equivalency trajectories of the restored Gog-Le-Hi-Te estuarine wetland," *Ecological Applications* 6, 38-56.

Analysis of 16 functional attributes of the restored Gog-Le-Hi-Ti (Lincoln Avenue) wetland in the Puyallup River estuary, Tacoma, WA, was conducted in order to test the ability to predict long-term trends and patterns in the development of a wetland restoration. Only a few of the attributes demonstrated functional trajectories towards equivalency in comparison with natural reference wetlands. Natural variability among reference sites hampered the interpretation of expected patterns of development. The lack of long-term data sets for restoration projects combined with the natural variability inherent to reference wetlands is a significant constraint to the ability of wetland managers to assess the benefits of compensatory mitigation measures. Alternative approaches to functional assessment of wetlands, such as controlled manipulative experiments, may be necessary in order to assess the performance of wetland restorations.

Sinicrope, T.L., Hine, P.G., Warren, R.S., and Neiring, W.A. (1990). "Restoration of an impounded salt marsh in New England," *Estuaries* 13, 25-30.

Vegetation communities were studied at a restored impounded marsh in Stonington, CT. Prior to reintroduction of tidal flooding, freshwater conditions prevailed and the marsh was dominated by *Typha angustifolia*. Ten years after reintroduction of tidal flooding, coverage of *Typha* and other brackish species had decreased from 74% to 16%. The salt marsh species *Spartina alterniflora* increased in coverage from <1% to 45%. Additional salt marsh species covered an additional 20% of the marsh. *Phragmites australis* was not affected by reintroduction of salt water, and coverage of this brackish species has increased.

Zedler, J. (1984). "Salt marsh restoration: A guidebook for southern California," California Sea Grant Report T-CSGCP-009.

A detailed "how-to" manual for the restoration and enhancement of salt marshes in southern California based on 6 years of intensive study in the Tijuana Estuary, Los Peñasquitos Lagoon, and the San Diego River. Definition of project goals and objectives are covered, as well as construction techniques, selection/ planting of salt marsh vegetation, monitoring, and storage/dissemination of project data. Additional sections provide information on regional coastal management policies, invasive exotics, and endangered species.

Zedler, J. B. (1996a). "Coastal mitigation in southern California: The need for a regional restoration strategy," *Ecological Applications* 6, 84-93.

The historic functioning of southern California coastal wetland systems is summarized, and four recent wetland mitigation case studies are used to document specific concerns and potential pitfalls. A regional strategy for restoration of coastal wetlands in southern California is proposed, along with recommendations for landscape-scale planning and implementation.

Zedler, J.B., Principal Author. (1996b). "Tidal wetland restoration: A scientific perspective and southern California focus," Report T-038, California Sea Grant System, University of California, La Jolla, CA.

This book represents an overview and synthesis of tidal wetland restoration in southern California. Examples of restoration projects, an overview of problems in wetland restoration, and recommendations for improved project planning and implementation (including discussion of the role of adaptive management) are presented. Considerable attention has been given to providing specific recommendations for data acquisition and monitoring of restored tidal wetlands.

Additional Entries

Abbe, T., Andrews, B., and Faber, P. (1991). "The physical evolution of a wetland restoration." *Coastal Zone '91, Proceedings of the Seventh Symposium on Coastal and Ocean Management*, July 8-12, 1991, Long Beach, California. O.T. Magoon, H. Converse, V. Tipple, L.T. Tobin, and D. Clark, eds., American Society of Civil Engineers, New York, 1732-46.

Abbe, T., Williams, P., and Faber, P. (1991). "Monitoring the physical evolution of tidal wetland restoration projects." *Coastal Zone '91, Proceedings of the Seventh Symposium on Coastal and Ocean Management, July 8-12, 1991, Long Beach, California*. O.T. Magoon, H. Converse, V. Tipple, L.T. Tobin, and D. Clark, eds., American Society of Civil Engineers, New York, 3618-26.

Adams, D.D., Darby, D.A., and Young, R.J. (1978a). "Habitat development field investigations, Windmill Point marsh development site, James River, Virginia. Appendix F: Environmental impacts of marsh development with dredged material: sediment and water quality. Vol. I: Characteristics of channel sediment before dredging and effluent quality during and shortly after marsh habitat development," Technical Report D-77-23, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Adams, D.D., Darby, D.A., and Young, R.J. (1978b). "Habitat development field investigations, Windmill Point marsh development site, James River, Virginia. Appendix F: Environmental impacts of marsh development with dredged material: sediment and water quality. Vol. II: Substrate and chemical flux characteristics of a dredged material marsh," Technical Report D-77-23, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

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Mangroves

Annotated Entries

Teas, H.J. (1977). "Ecology and restoration of mangrove shorelines in Florida," *Environmental Conservation* 4, 51-58.

The life-history and ecological role of mangroves in south Florida is summarized. Significant acreage of mangroves has been lost in south Florida, primarily due to dredge and fill activities, and restoration of impacted areas is necessary to reestablish lost functions. Several efforts to transplant mangroves are described. Important factors in the successful reestablishment of planted mangroves include plant size and source, salinity regime, shoreline energy, water depth, root-parasite prevalence, and vandalism. Cost estimates for planting various mangrove species are provided.

Vose, F.E., and Bell, S.S. (1994). "Resident fishes and macrobenthos in mangrove-rimmed habitats: Evaluation of habitat restoration by hydrologic modification," *Estuaries* 17, 585-96.

Fish and macrobenthic communities were studied at a mangrove-dominated impoundment (Cabbagehead Bayou, Tampa Bay, Florida) and at a nearby reference site (Double Branch Bay). Faunal samples were collected 13 months prior and 22 months after removal of a berm. Fish abundance, biomass, and species richness decreased in Cabbagehead Bayou as a result of berm removal. Macrofaunal response was variable among taxa, but amphipod and polychaete abundances increased following berm removal. Community similarity of fish and polychaete and amphipod assemblages between the two sites increased during the second year of postrestoration monitoring, but generally remained low. Although a distinct faunal response to alteration of tidal regime may be detectable within 2 years, the authors recommend that future studies which attempt to document faunal recovery of restored wetlands may benefit from extended duration of monitoring.

Additional Entries

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Seagrasses

Annotated Entries

Fonseca, M.S., and Fisher, J.S. (1986). "A comparison of canopy friction and sediment movement between four species of seagrass with reference to their ecology and restoration," *Marine Ecology Progress Series* 29, 15-22.

The ability of seagrasses to modify the hydrodynamic environment is well-documented and may affect the observed distribution of fauna associated with existing or newly developing seagrass meadows. Comparisons of canopy friction and sediment dispersal were made for four species of seagrasses (*Thalassia testudinum*, *Halodule wrightii*, *Zostera marina*, and *Syringodium filiforme*) under 27 combinations of velocity, water depth, and plant density in an experimental flume. All species except *S. filiforme* lost friction (through canopy compression) with increasing current velocity. Canopy fraction was positively correlated with the percent of the water column occupied by seagrasses. *Thalassia testudinum* provide the greatest protection of the sediment surface from erosion; *H. wrightii* and *Z. marina* provided intermediate levels of protection; and *S. filiforme* provided the least protection. Nursery and refuge characteristics of the four species are likely to vary directly with their influence on canopy friction and sediment movement. Future studies of seagrass fauna should consider hydrodynamic factors.

Fonseca, M.S., Kenworthy, W.J., and Courtney, F.X. (1996). "Development of planted seagrass beds in Tampa Bay, Florida, USA. I. Plant components," *Marine Ecology Progress Series* 132, 127-39.

This paper documents the study of floral attributes of planted seagrass beds (*Halodule wrightii* and *Syringodium filiforme*) in Tampa Bay, Florida. Planting Unit (PU) survival, change in areal shoot density, plant morphometrics and associated macroalgae were monitored for 3 years (1987-90), with comparison to nearby, natural reference beds. An average loss of 47 percent PU was documented, although subsequent survival and persistence indicate that many areas of Tampa Bay are now suitable for restoration. Many plantings exhibited little growth during year one, and then expanded rapidly in year two of the study. Conservation of remaining seagrass beds provides a more certain basis for maintaining the resource than mitigation through planting.

Fonseca, M.S., Kenworthy, W.J., Colby, D.R., Rittmaster, K.A., and Thayer, G.W. (1990). "Comparisons of fauna among natural and transplanted eelgrass *Zostera marina* meadows: Criteria for mitigation," *Marine Ecology Progress Series* 65, 251-64.

In this paper, abundance, composition, and size distributions of fish and shrimp were compared among unvegetated, transplanted, recently seed-colonized, and mature, natural eelgrass (*Zostera marina*) habitats in order to determine the functional equivalence of transplanted beds to natural counterparts. Fish and shrimp were most abundant in natural eelgrass beds, and least abundant in unvegetated habitats. Epibenthic faunal development was closely coupled with eelgrass bed development. Areas characterized by poor transplant success exhibited reduced abundance and different taxonomic composition relative to natural beds. Animal abundance in a successful 1.9-year-old transplanted bed and a 6-month-old seed-developed bed was indistinguishable from that of mature, natural beds. Areal shoot density may serve as a convenient diagnostic parameter to determine functional equivalency in transplanted eelgrass beds. Restoration of eelgrass habitats may contribute substantially to fish and shrimp production, provided the habitats persist.

Fonseca, M.S., Meyer, D.L., and Hall, M.O. (1996). "Development of planted seagrass beds in Tampa Bay, Florida, USA. II. Faunal components," *Marine Ecology Progress Series* 132, 141-56.

This paper documented changes in shrimp, fish, and crab abundance and composition and size distribution in planted *Halodule wrightii* and *Syringodium filiforme* beds in Tampa Bay, Florida. Faunal samples were collected using 1-m² dropnets over a 3-year period (1987-90) with comparison to unvegetated habitats and nearby natural reference beds. Planted *H. wrightii* beds exhibited animal densities and species composition comparable with that of natural beds 1.8 years after planting. Comparison of *S. filiforme* and *S. filiforme/H. wrightii* mixed beds were unavailable due to failure of several planting areas. Macroepifauna in planted *H. wrightii* beds exhibited an asymptotic relationship with areal shoot density, with animal densities equaling natural beds at shoot densities of one-third that of natural beds. This pattern corroborates the existence of a threshold for habitat structure influencing numerical abundance of associated animal communities in seagrass beds.

McLaughlin, P.A., Treat, S.F., Thorhaug, A., and Lemaitre, R. (1983). "A restored seagrass (*Thalassia*) bed and its animal community," *Environmental Conservation* 10, 247-54.

The animal community of a restored *Thalassia* bed in south Biscayne Bay, Florida, was sampled quarterly to determine whether recolonization would be similar to a natural *Thalassia* bed, unaffected by thermal effluent or other pollutants. Significant differences in abundance and species composition were found in comparison of the restored *Thalassia* bed to a nearby, unvegetated area. No statistically significant differences were observed in comparison to the unimpacted control site. Certain animal groups (*Penaeus duorarum*, caridean shrimps,

juvenile fishes) were more abundant in the restored bed relative to the unimpacted control site.

Orth, R.J., Luckenbach, M., and Moore, K.A. (1994). "Seed dispersal in a marine macrophyte: Implications for colonization and restoration," *Ecology* 75, 1927-39.

Field and laboratory experiments on seed dispersal in eelgrass (*Zostera marina* L.) were conducted in the York River, Virginia. Results showed that seeds settle rapidly, with dispersal distances of only a few meters from broadcast sites, and are rapidly incorporated into the substrate. Small-scale topographic features (burrows, mounds, etc.) may shield seeds from the effects of bottom currents. The limited dispersal capabilities of seeds and landscape-scale implications for eelgrass patch dynamics and establishment/recolonization should be considered in the formulation of eelgrass restoration goals.

Thom, R.M. (1990). "A review of eelgrass (*Zostera marina* L.) transplanting projects in the Pacific Northwest," *The Northwest Environmental Journal* 6, 121-37.

This paper reviews 17 eelgrass transplanting projects conducted on the U.S. west coast from northern California to British Columbia. Key factors influencing the success of eelgrass transplanting projects are discussed, and specific recommendations to increase planting success are summarized. Research is needed on the functional performance of transplanted eelgrass beds in the Pacific northwest. Development of a comprehensive regional database on eelgrass transplanting projects is recommended.

Thorhaug, A. (1986). "Review of seagrass restoration efforts," *Ambio* 15, 110-17.

This review paper documents human and natural perturbations affecting seagrass habitats, discusses the primary ecological functions of seagrasses, and outlines the various methods that have been used to restore seagrass habitat. Over 165 restoration attempts worldwide were considered in this review; of these, 75 were considered to be successful. Factors in the recovery process are discussed, and cost estimates for various restoration methods are given. Management implications and policy recommendations for seagrass habitat restoration, including the protection of existing resources, are suggested.

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Miscellaneous

Annotated Entries

NRC. (1994). *Restoring and protecting marine habitat: The role of engineering and technology*. National Academy Press, Washington, DC.

This report addresses the role of technology in protecting and restoring marine habitat, with emphasis on coastal wetlands. Scientific and engineering perspectives on habitat protection and restoration are presented, along with an analysis of the state of the art in coastal engineering technology. Impediments to implementation of engineering technology are discussed, along with a summary of institutional constraints, research needs, and methods for the evaluation of project success. Several case studies illustrate the application of engineering technology to habitat protection and enhancement in the coastal zone.

Thayer, G.W. (1992). *Restoring the Nation's marine environment*. Maryland Sea Grant, College Park, MD.

This book is a compilation of selected papers from a NOAA-sponsored symposium on habitat restoration, held in Washington, DC, on September 25-26, 1990. Salt marshes in California and North Carolina, urban estuaries, seagrass meadows, coral reefs, kelp beds, and mangroves are among the many habitats covered. Transcripts of panel discussions on current U.S. efforts to restore habitat and future directions and research needs in habitat restoration are included.

Additional Entries

Ashe, D.M. (1982). "Fish and wildlife mitigation: Description and analysis of estuarine applications," *Coastal Zone Management Journal* 10, 1-52.

Banner, A. (1977a). "Revegetation and maturation of restored shoreline in the Indian River, Florida." *Proceedings of the 4th Annual Conference on Restoration of Coastal Vegetation in Florida, May 14, 1977, Hillsborough Community College, Tampa, Florida*. R.R. Lewis III and D.P. Cole, eds., 13-43.

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 Hoffman et al. 1985
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 Llewellyn and Shaffer 1993
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 Phillips 1980a,b,c
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 Crewz and Moffler 1984
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 Teas 1977, 1980, 1981
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 Woodhouse 1979
- Lake Pontchartrain
 Boumans et al. 1993
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 Beeman 1992
- Littorina irrorata*
 Krebs and Tanner 1981a
- Los Penasquitas Lagoon
 Zentner 1988
- Louisiana
 Baumann and Adams 1981
 Boumans et al. 1993
 Chabreck 1990
 Cheramie et al. 1995
 DeMond et al. 1986
 Ensminger and Binet 1993
 Gunn 1987
 Hartman et al. 1994
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 Thomas 1995
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 Fruge 1995
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 Webb 1982
 Zobrist et al. 1995
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 Shisler 1990
- mariculture
 Thorhaug 1990
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 Batiuk et al. 1992
 Earhart and Garbisch 1983
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 Garbarino et al. 1994
 Kollar 1985
 Shisler 1990
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 Lewis 1981, 1982c, 1990b
 Pulver 1976
 Thorhaug 1990
 Vose and Bell 1994
- Ensminger and Binet 1993

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 Portnoy et al. 1987
 Shisler 1990
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 Landin and Webb 1986
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- Manayunkia aesturina*
 Moy and Levin 1991
- meiofauna
 Boyd 1982
 Diaz et al. 1978
 Lunz et al. 1978
 Virginia Institute of Marine
 Science 1978
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 Fell et al. 1991
 Peck et al. 1994
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 Lunz 1978
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 Cole 1978
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 Chabreck 1990
 Eleuterius and McClellan 1976
 Hawes 1984, 1990
 Landin 1984
 Snyder 1982
- Mississippi River Delta
 Gunn 1987
 Landin 1984
- Mobile Bay
 Landin 1984, 1986
 Stout and Heck 1989
- monitoring
 Abbe et al. 1991
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 Crewz and Lewis 1991
 Fonseca 1990, 1992
 Josselyn and Bucholz 1984
- Roman et al. 1995
- Delaune et al. 1984
 Landin and Newling 1988
 Moy and Levin 1991
- Reimold et al. 1978
- Eleuterius 1975
 Gunn 1987
 Kruczynski 1982
 LaSalle 1996
- Hawes 1984, 1990
- Landin and Webb 1986
 Webb et al. 1984, 1988
- Beeman 1992
 Chabreck 1990
 Faber et al. 1988
 Frenkel and Morlan 1991
 Lewis 1990

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| Morrison and Williams 1988 | Newling et al. 1983 |
| Shisler 1990 | Webb et al. 1978 |
| Zedler 1988 | Zedler et al. 1982 |
| <i>Monoanthochloe littoralis</i> | |
| Beeman 1992 | |
| <i>Morone americana</i> | |
| Dias et al. 1978 | |
| mosquito control | |
| Ferrigno et al. 1987 | Portnoy et al. 1987 |
| Shisler and Charette 1984b | Slavin et al. 1978 |
| <i>Myocastor coypus</i> | |
| Ensminger and Binet 1993 | Llewellyn and Shaffer 1993 |
| Naples Bay | |
| Stephen 1983 | |
| neuston | |
| Shreffler et al. 1992 | |
| New Hampshire | |
| Shisler 1990 | |
| New Jersey | |
| Charette et al. 1985 | Ferrigno et al. 1987 |
| Kraus and Smith 1986 | Kraus and Kraus 1986 |
| Matsil and Bergen 1995 | Shisler and Charette 1984a,b;
1986a |
| Shisler 1990 | Slavin et al. 1978 |
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| New York | |
| Churchill et al. 1978 | LaPerriere and Farmer 1988,
1989 |
| Matsil and Bergen 1995 | Ristich et al. 1976 |
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| nitrogen | |
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| Craft et al. 1988 | Currin et al. 1996 |
| Gibson et al. 1994 | Langis et al. 1991 |
| McVay et al. 1980 | Wilsey et al. 1992 |

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Broome 1990

Broome et al. 1983, 1986
Cammen et al. 1976
Currin et al. 1996
Fonseca et al. 1990
Kenworthy and Fonseca 1992
Moy and Levin 1991
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Seneca et al. 1976
Smith et al. 1989
Thayer et al. 1989
Woodhouse et al. 1972a,b; 1974

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Craft et al. 1988, 1991
Fonseca et al. 1985
Homziak et al. 1992
Linthurst and Seneca 1980
Seneca 1974, 1980
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Seneca et al. 1985a,b
Thayer et al. 1975
Woodhouse and Knutson 1982

Notropis hudsonius

Dias et al. 1978

oil spills

Broome et al. 1988
Getter et al. 1984
Krebs and Tanner 1981a,b
Matsil and Bergen 1995
Zieman et al. 1984

Delaune et al. 1984
Hartman et al. 1994
Maiero et al. 1978
Touchette et al. 1992

oligochaetes

Diaz and Boesch 1978

Diaz et al. 1978

Oncorhynchus spp.

Shreffler et al. 1990, 1992

Oregon

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Coenen and Cortright 1979
Cutshall and Johnson 1977
Frenkel and Morlan 1991
Heilman et al. 1978
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Landin and Webb 1986
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McConnell et al. 1978
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Smith 1978, 1980
Thom 1990
Woodward-Clyde Consultants 1978

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Crawford and Edwards 1978
Environmental Laboratory 1978
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Kentula 1986
Landin 1986, 1993
Landin et al. 1987
Lightcap 1987
McVay et al. 1980
Simenstad and Thom 1992
Ternyik 1978, 1980
Williams and Zedler 1992

Panicum virgatum

Garbisch et al. 1975

Paspalum spp.

Beeman 1992
Clark 1992
Knutson and Woodhouse 1983

Peltandra virginica

Garbisch and Coleman 1978
Lunz et al. 1978
Lunz 1978
Shisler 1990

phosphorus

Broome et al. 1975a,b
Craft et al. 1988
Wilsey et al. 1992
Broome et al. 1983
McVay et al. 1980

Phragmites australis (communis)

Bongiorno et al. 1984
Garbisch et al. 1975
Kraus and Kraus 1986
Kruczynski 1982
Roman et al. 1984
Shisler 1990
Steinke 1988
Woodhouse and Knutson 1982
Eleuterius and McClellan 1976
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Kraus and Smith 1986
LaPerriere and Farmer 1988
Rozsa 1988
Sinicrope et al. 1990
Woodhouse 1979

plant propagation/planting techniques

Allen et al. 1978
Barko and Smart 1976
Boone and Hoeppel 1976
Broome et al. 1973, 1974
Carlton and Moffler 1978
Cintron-Molero 1992
Clark 1989
Crawford and Edwards 1978
Crewz and Lewis 1991
Derrenbacker and Lewis 1982
Durako and Moffler 1981, 1984
Eleuterius and McClellan 1976
Banner 1977
Barko et al. 1977
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Dunstan et al. 1975
Eleuterius 1975
Environmental Laboratory 1978

Evans 1977

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Knutson and Woodhouse 1982, 1983
Kruczynski 1982
Lewis and Lewis 1977

Falco and Cali 1977

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Garbisch 1977, 1978
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Kelly et al. 1971
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- Seidensticker 1994
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- Tanner and Dodd 1985
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- Teas 1977, 1981
- Thayer et al. 1985a
- Thorhaug and Austin 1976
- Webb 1982
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- Woodhouse 1979
- Woodhouse et al. 1972a,b; 1974
- Zedler 1984
- Pontedaria cordata*
- Garbisch and Coleman 1978
- porewater chemistry
- Craft et al. 1991
- Potomac River
- Batiuk et al. 1992
- Smith 1978, 1980
- Palermo and Ziegler 1976, 1977
- Potamogeton spp.*
- Kollar 1985
- Puerto Rico
- Lewis 1990a
- Puget Sound
- Clark and Francisco 1995
- Phillips 1974; 1980a,b
- Shreffler and Thom 1993
- Simenstad et al. 1991
- Landin 1993
- Phillips and Lewis 1983
- Simenstad and Thom 1992
- Puyallup River
- Shreffler et al. 1990, 1992
- Thom et al. 1987
- Simenstad and Thom 1992, 1996
- Rallus longirostris*
- Miner 1994
- Zedler 1996a
- Reithrodontomys raviventris*
- Miner 1994

Rhizophora mangle

Banner 1977
Carlton and Moffler 1978
Crewz and Moffler 1984
Dial et al. 1985
Knutson and Woodhouse 1983
Lewis and Dunstan 1975
Lewis et al. 1979
Pulver 1976
Stephen 1983
Thorhaug 1990
Vose and Bell 1994

Birkitt 1983
Crewz and Lewis 1991
Darovec et al. 1975
Hoffman et al. 1985
Lewis 1979, 1981, 1982c, 1990b
Lewis and Haines 1981
Markley et al. 1992
Shirley 1992
Teas 1977, 1980, 1981
Touchette et al. 1992
Woodhouse 1979

Rhode Island

Shisler 1990

Rookery Bay

Shirley 1992

Ruppia maritima

Clark 1989
Fonseca 1994
Phillips 1980a,b,c
Thorhaug 1986

Darovec et al. 1975
Lewis et al. 1982
Thayer et al. 1985a,b

Sagittaria spp.

Maguire and Heuterman 1978
Shisler 1990

Salicornia spp.

Abbe et al. 1991
Birkitt 1983
Faber et al. 1988
Knutson 1976
Landin et al. 1991
Maguire and Heuterman 1978
Sinicrope et al. 1990
Zedler 1996a

Abbe et al. 1991
Cuneo 1987
Frenkel and Morlan 1991
Knutson and Woodhouse 1982
LaPerriere and Farmer 1988
Shisler 1990
Woodhouse 1979

Salmon River

Frenkel and Morlan 1991
Simenstad and Thom 1992

Kentula 1986

salt ponds

Cogswell 1981
Landin 1986
Morris et al. 1978
Niesen and Lyke 1981
Woods 1981

Josselyn and Perez 1981
Landin et al. 1991
Niesen and Josselyn 1981
Smith 1978

San Diego Bay

Boone and Hoeppel 1976
Josselyn and Bucholz 1982
Zedler 1988; 1992; 1996a,b
Zentner 1988

Gibson et al. 1994
Langis et al. 1991
Zedler and Langis 1991

San Francisco Bay

Abbe et al. 1991
Barker et al. 1993
Coats and Williams 1980
Cuneo 1987
Faber et al. 1988
Gale and Williams 1988
Haltiner and Williams 1987
Josselyn and Perez 1981
Josselyn et al. 1987
Landin 1984, 1986, 1993
Marcus 1993
Miner 1994
Morrison and Williams 1988
Niesen and Lyke 1981
Siegel 1989
Sorensen et al. 1979
Wittenberg 1990
Zentner 1988

Abbe et al. 1991
Boyd 1982
Cogswell 1981
Environmental Laboratory 1978
Faber 1991
Goodwin and Williams 1992
Harvey and Josselyn 1986
Josselyn and Bucholz 1982, 1984
Knutson 1976
Landin et al. 1991
Mason 1980
Morris et al. 1978
Niesen and Josselyn 1981
Race 1985, 1986
Smith 1978, 1980
Wakeman 1982
Woods 1981

Santa Ana River

Newling 1982

Sarasota Bay

Edwards 1994

Sauers 1981

Scirpus spp.

Abbe et al. 1991
Barko and Smart 1976
Garbisch et al. 1975
Maguire and Heuterman 1978
Ternyik 1980

Abbe et al. 1991
Barko et al. 1977
Lunz et al. 1978
Shisler 1990
Woodhouse 1979

sedimentation

Barker et al. 1993
Faber 1991
Krone 1982
Williams and Harvey 1983

Boumans et al. 1993
Josselyn and Bucholz 1984
Ray and Woodroof 1986

seed dispersal

Orth et al. 1994

Sesuvium portulacastrum

Beeman 1992

shoreline/substrate stabilization

Broome 1990
Cammen 1975
Eleuterius 1975
Ensminger and Binet 1993
Fonseca et al. 1985
Garbisch 1977
Josselyn 1986
Knutson and Innskeep 1982
Knutson et al. 1981
Phillips et al. 1978
Seneca et al. 1976
Tanner and Dodd 1985
Webb et al. 1984
Woodhouse and Knutson 1982

Broome et al. 1983, 1986
Chabreck 1990
Eleuterius and McClellan 1976
Fonseca et al. 1982, 1987
Garbisch et al. 1975
Josselyn and Bucholz 1984
Knutson 1977
Knutson and Woodhouse 1983
Lewis 1990b
Seneca 1974, 1980
Seneca et al. 1985a
Webb 1982
Woodhouse 1979
Woodhouse et al. 1972b, 1974

Snohomish River

Simenstad and Thom 1992

soils

Adams et al. 1978a,b
Barko and Smart 1976
Broome 1990
Broome et al. 1988
Chabreck 1990
Craft et al. 1991
Garbisch 1977
Heilman et al. 1978
Langis et al. 1991
Lindau and Hossner 1982
Lunz et al. 1978
Moy and Levin 1991
Shisler 1990
Virginia Institute of Marine
Science 1978
Wetzel and Powers 1978

Allen et al. 1978
Barko et al. 1977
Broome et al. 1975a
Cammen 1975
Clairain et al. 1978
Currin et al. 1996
Gibson et al. 1994
Krone 1982
Lewis 1990
Lunz 1978
Lunz et al. 1978
Reimold et al. 1978
Shisler and Charette 1984a

Webb et al. 1978

Solidago sempervirens

Bongiorno et al. 1984
Frankowski et al. 1977

South Carolina

LaSalle et al. 1991

Spartina alterniflora

Allen et al. 1994
Barko and Smart 1976
Beeman 1992
Boumans et al. 1993
Broome et al. 1973, 1974, 1975a,b

Banner 1977
Barko et al. 1977
Bongiorno et al. 1984
Broome 1990
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Broome et al. 1988
 Cammen 1976a,b
 Chabreck 1990
 Craft et al. 1988, 1991
 Currin et al. 1996
 Delaune et al. 1984
 Dunstan et al. 1975
 Earhart and Garbisch 1983
 Fell et al. 1991
 Garbisch et al. 1975
 Havens et al. 1995
 Hoffman et al. 1985
 Knutson and Woodhouse 1983
 Kraus and Kraus 1986
 Kruczynski 1982
 Larimer 1968
 LaSalle et al. 1991
 Lewis and Lewis 1977
 Lewis 1982b, 1990b
 Lunz et al. 1978
 Markley et al. 1992
 Matthews and Minello 1994a,b
 Minello and Webb 1993
 Minello et al. 1987
 Moy and Levin 1991
 Peck et al. 1994
 Rennie 1990
 Roman et al. 1984
 Seidensticker 1994
 Seneca and Broome 1992
 Seneca et al. 1976
 Shisler 1990

 Sinicrope et al. 1990
 Steinke 1988
 Terry et al. 1974
 Touchette et al. 1992
 Webb and Newling 1985
 Webb et al. 1984
 Webb et al. 1988
 Woodhouse 1979
 Woodhouse et al. 1972a,b; 1974

Spartina cynosuroides

Broome 1990
 Garbisch et al. 1975
 Kruczynski 1982
 Maguire and Heuterman 1978

Cammen 1975
 Cammen et al. 1976
 Clark 1992
 Crewz and Lewis 1991
 Darovec et al. 1975
 Dial et al. 1985
 Earhart 1988
 Eleuterius and McClellan 1976
 Ferrigno et al. 1987
 Hartman et al. 1994
 Hoffman and Rodgers 1981
 Knutson and Innskeep 1982
 Kraus and Smith 1986
 Krebs and Tanner 1981a,b
 LaPerriere and Farmer 1988
 LaSalle 1996
 Lefor et al. 1987
 Lewis et al. 1979
 Linthurst and Seneca 1980
 Maguire and Heuterman 1978
 Matsil and Bergen 1995
 Meyer et al. 1993
 Minello and Zimmerman 1992
 Minello et al. 1994
 Patrick et al. 1984
 Reimold et al. 1978
 Roberts 1989, 1991
 Rozsa 1988
 Seneca 1974, 1980
 Seneca et al. 1975
 Seneca et al. 1985a,b
 Shisler and Charette 1984a,
 1986a
 Sipocz 1994
 Tanner and Dodd 1985
 Thayer et al. 1989
 Webb 1982
 Webb et al. 1978
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 Wilsey et al. 1992
 Woodhouse and Knutson 1982

Eleuterius and McClellan 1976
 Knutson and Woodhouse 1983
 Lunz et al. 1978
 Reimold et al. 1978

Shisler 1990
Woodhouse and Knutson 1982

Woodhouse 1979

Spartina foliosa

Abbe et al. 1991
Barko and Smart 1976
Faber et al. 1988
Gibson et al. 1994
Josselyn and Bucholz 1982, 1984
Knutson 1976
Knutson and Woodhouse 1982, 1983
Langis et al. 1991
Woodhouse 1979

Abbe et al. 1991
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Faber 1991
Josselyn 1986
Josselyn and Perez 1981
Knutson and Innskeep 1982
Landin et al. 1991
Maguire and Heuterman 1978
Zedler 1983, 1992, 1996a

Spartina patens

Allen et al. 1994
Barko et al. 1977
Bongiorno et al. 1984
Chabreck 1990
Earhart 1988
Eleuterius and McClellan 1976
Ferrigno et al. 1987
Garbisch et al. 1975
Hoffman et al. 1985
Kruczynski 1982
Larimer 1968
Lewis 1990b
Patrick et al. 1984
Reimold et al. 1978
Roman et al. 1984
Shisler and Charette 1984a, 1986a
Slavin et al. 1978
Steinke 1988
Webb 1982
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Barko and Smart 1976
Beeman 1992
Broome 1990
Darovec et al. 1975
Earhart and Garbisch 1983
Fell et al. 1991
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Lefor et al. 1987
Maguire and Heuterman 1978
Peck et al. 1994
Rennie 1990
Shisler 1990
Sinicrope et al. 1990
Slavin and Shisler 1983
Thayer et al. 1989
Webb et al. 1978
Webb et al. 1988
Woodhouse and Knutson 1982

Sporobolus virginicus

Beeman 1992

St. Andrews Bay
Fonseca et al. 1987

St. Joseph Bay
Phillips 1977
Phillips et al. 1978

Streblospio benedicti

Moy and Levin 1991

Suisan Bay

Sorensen et al. 1979

Syringodium filiforme

Darovec et al. 1975
Eleuterius and McClellan 1976
Fonseca and Fisher 1986
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Fonseca et al. 1996
Hoffman et al. 1985
Lewis and Phillips 1981
Phillips 1980a,b,c; 1982
Thorhaug 1985, 1986, 1990
Zieman et al. 1984

Eleuterius 1975
Fonseca 1990, 1994
Fonseca et al. 1984
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Lewis 1987
Lewis et al. 1982
Thayer et al. 1985a, 1990
Thorhaug and Austin 1976

Tampa Bay

Clark 1989, 1992
Dial and Deis 1986
Fonseca et al. 1996
Fuss and Kelly 1969
Hoffman et al. 1985
Lewis 1982a
Lewis and Lewis 1977
Lewis et al. 1982
Pulver 1976
van Breedveld 1975

Dial et al. 1985
Durako and Moffler 1981
Fonseca et al. 1996
Hoffman and Rodgers 1981
Kelly et al. 1971
Lewis and Dunstan 1975
Lewis et al. 1979
Phillips 1980
Robison 1995
Vose and Bell 1994

Texas

Allen et al. 1978
Chabreck 1990
Environmental Laboratory 1978
Landin 1984, 1986
Lindau and Hossner 1981, 1982
Lyon and Baxter 1978
Minello and Zimmerman 1992
Minello et al. 1994
Pitre 1981
Rozas and Zimmerman 1994
Sipocz 1994
Tanner and Dodd 1985
Webb 1982
Webb et al. 1978
Webb et al. 1988

Bass 1995
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Kindle 1994
Landin and Webb 1986
Lunz et al. 1978
Minello and Webb 1993
Minello et al. 1987
Phillips 1980a,b
Rennie 1990
Seidensticker 1994
Smith 1978a,b; 1980
Thayer et al. 1989
Webb and Newling 1985
Webb et al. 1984

Thalassia testudinum

Austin and Thorhaug 1977
Derrenbacker and Lewis 1982
Eleuterius 1975
Fonseca 1994

Darovec et al. 1975
Durako and Moffler 1981, 1984
Eleuterius and McClellan 1976
Fonseca and Fisher 1986

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 Fuss and Kelly 1969
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 Lewis and Phillips 1981
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 Phillips 1976; 1980a,b,c; 1982
 Sauers 1981
 Thorhaug 1974; 1976; 1979a,b; 1980a,b;
 1983; 1985; 1986; 1990
 Van Breedveld 1975
- Tijuana River
 Florsheim et al. 1991
 McCreary and Zentner 1983
 Zentner 1988
- Timbalier Bay
 Hartman et al. 1994
- Triglochin maritima*
 Barko and Smart 1976
 Kentula 1986

 Woodhouse 1979
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 Fell et al. 1991
 Lunz 1978
 Ristich et al. 1976
 Shisler 1990
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 Kraus and Kraus 1986
- U.S. Virgin Islands
 Lewis 1979, 1990a
- Vallisneria americana*
 Kollar 1985
- Virginia
 Adams et al. 1978a,b
 Dias et al. 1978
 Diaz et al. 1978
 Environmental Laboratory 1978
 Havens et al. 1995
 Landin and Newling 1988
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 Hoffman et al. 1985
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 McLaughlin et al. 1983
 Phillips and Lewis 1983
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 Thorhaug and Austin 1976
 Zieman et al. 1984
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 Zedler 1988, 1992
- Barko et al. 1977
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- Garbisch et al. 1975
 Peck et al. 1994
 Rozsa 1988
 Sinicrope et al. 1990
- Lewis and Haines 1981
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 Diaz and Boesch 1978
 Doumlele and Silberhorn 1978
 Garbisch 1978
 Landin 1984
 Lunz 1978

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 Orth and Moore 1982
 Palermo and Ziegler 1976, 1977
 Silberhorn and Barnard 1977
 Virginia Institute of Marine
 Science 1978
 Wetzel and Powers 1978
- Washington
 Blomberg 1987
 Cooper 1987
 Knutson and Woodhouse 1982
 Phillips 1974; 1980a,b
 Shreffler and Thom 1993
 Simenstad and Thom 1992, 1996
 Smith 1978
 Thom 1990
 Vincent 1978
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 Adams et al. 1978a,b
 Krone 1982
 Lunz et al. 1978
- wildlife
 Allen et al. 1978
 Bass 1995
 Boyd 1982
 Cole 1978
 Josselyn and Bucholz 1984
 LaSalle 1996
 Portnoy et al. 1987
 Roberts 1991
 Virginia Institute of Marine
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 Webb et al. 1978
- Winyah Bay
 LaSalle et al. 1991
- York River
 Batiuk et al. 1992
 Orth et al. 1994
- zooplankton
 Clairain et al. 1978
- Moore and Orth 1982
 Orth et al. 1994
 Shisler 1990
 Smith 1978, 1980
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- Clark and Francisco 1995
 Kentula 1986
 Landin 1993
 Phillips and Lewis 1983
 Shreffler et al. 1990, 1992
 Simenstad et al. 1991
 Tanner 1992
 Thom et al. 1987
 Williams and Zedler 1992
- Batiuk et al. 1992
 Lunz et al. 1978
 Reimold et al. 1978
- Ashe 1982
 Beeman 1992
 Clairain et al. 1978
 Crawford and Edwards 1978
 Landin and Newling 1988
 Lunz et al. 1978
 Roberts 1989
 Simenstad et al. 1991
- Wass and Wilkins 1978
- Havens et al. 1995
- Havens et al. 1995

Zostera marina

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| Boone and Hoeppel 1976 | Churchill et al. 1978 |
| Fonseca 1987, 1990 | Fonseca and Fisher 1986 |
| Fonseca et al. 1982a,b | Fonseca et al. 1985 |
| Fonseca et al. 1987 | Fonseca et al. 1988 |
| Fonseca et al. 1990 | Homziak et al. 1982 |
| Kentula 1986 | Kenworthy and Fonseca 1977,
1992 |
| Meyer et al. 1993 | Moore and Orth 1982 |
| Orth and Moore 1982 | Orth et al. 1994 |
| Phillips 1974; 1976; 1980a,b,c; 1982 | Phillips and Lewis 1983 |
| Smith et al. 1989 | Thayer et al. 1975 |
| Thayer et al. 1985a, 1990 | Thayer et al. 1989 |
| Thom 1990 | Thorhaug 1980a, 1986, 1990 |
| Thorhaug and Austin 1976 | Zieman et al. 1984 |

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13. ABSTRACT (Maximum 200 words) This bibliography was compiled to provide biologists, engineers, and planners at Corps Districts and other agencies/institutions with a guide to the diverse body of literature on coastal wetland restoration. The availability of this information should aid in the development of technically sound restoration plans and guide efforts to evaluate wetland restoration projects in the coastal zone using the best information available. This bibliography consists of 435 literature citations on coastal wetland restoration in the United States. Sources include scientific journals, conference proceedings, and technical reports from various Federal and State agencies. The bibliography is organized by the following wetland habitat types: (a) tidal marshes, (b) mangroves, (c) seagrasses, and (d) miscellaneous. Selected key citations in each section are briefly annotated, and a subject index is provided.			
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